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STANDARDIZED CATCH RATES FOR BLUE MARLIN (*Makaira nigricans*) AND WHITE MARLIN (*Tetrapturus albidus*) FROM THE PELAGIC LONGLINE FISHERY IN THE NORTHWEST ATLANTIC AND THE GULF OF MEXICO

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SUMMARY

Indices of abundance of blue marlin (Makaira nigricans) *and white marlin* (Tetrapturus albidus) *from the United States pelagic longline fishery in the Atlantic are presented for the period 1986-1999. The index of weight (kg) per number of hooks (in thousands) was estimated from numbers of billfish caught and reported in the logbooks submitted by commercial fishermen, and from mean annual weights estimated by scientific observers of the Pelagic Observer Program onboard longline vessels since 1992. The standardization procedure included the following variables: Year, Area, Season, Gear characteristics (use of light sticks, main line length, hook density, etc) and Fishing characteristics (bait type, operation procedure, and target species). The Pelagic Observer Program collects detailed information that allowed for the evaluation of the relationships between billfish catch rates and other fishing variables (hook type and size, main line material and size, rattlers, gangion size and material, etc) or environmental variables (sea-surface temperature, weather condition, wind) for the US longline fishery. The standardized index was obtained using Generalized Linear Mixed Models under a delta-lognormal model approach.*

RÉSUMÉ

Le présent document présente les indices d'abondance du makaire bleu (Makaira nigricans) *et du makaire blanc* (Tetrapturus albidus) *capturés par les palangriers pélagiques américains dans l'Atlantique pendant la période 1986-1999. L'indice en poids (kg) par nombre d'hameçons (en milliers) a été estimé d'après le nombre d'istiophoridés capturés et déclarés dans les livres de bord remis par les pêcheurs commerciaux, et le poids annuel moyen estimé par les observateurs scientifiques du Pelagic Observer Program à bord de palangriers depuis 1992. Le processus de standardisation comprenait les variables suivantes: année, zone, saison, caractéristiques des engins (utilisation de bâtons lumineux, longueur de la ligne principale, densité des hameçons, etc.) et les caractéristiques de la pêche (type d'appât, processus opératif et espèce-cible). Le Pelagic Observer Program collecte une information détaillée qui a permis d'ávaluer la relation entre le taux de capture des istiophoridés et les autres variables de la pêche (type et dimensions des hameçons, matériau et dimensions de la ligne principale, klaxons d'alarme, dimensions et matériau des avançons, etc.) ou celles de l'environnement (température de surface, conditions météo, vent) en ce qui concerne la pêche palangrière américaine. L'indice standardisé a été obtenu au moyen de modèles linéaires généralisés mixtes selon une approche modélique delta-lognormal.*

RESUMEN

Se presentan, para el periodo 1986-1999, índices de abundancia de la aguja azul (Makaira nigricans) *y aguja blanca* (Tetrapturus albidus) *de la pesquería de palangre pelágico de Estados Unidos en el Atlántico. El índice de peso (kg) por número de anzuelos (en miles) se estimó a partir del número de marlines capturados y comunicados en los cuadernos de pesca enviados por los pescadores comerciales, y a partir de los pesos medios anuales estimados por los observadores científicos del Programa de Observadores Pelágicos, embarcados en palangreros desde 1992. El*

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procedimiento de estandarización incluía las siguientes variables: año, área, temporada, características del arte (uso de bastones luminosos, longitud de la línea madre, densidad de los anzuelos, etc) y características de la pesca (tipo de cebo, procedimientos de operación y especies objetivo). El Programa de Observadores Pelágicos recopila información detallada que permita la evaluación de las relaciones entre tasas de captura de marlines y otras variables de la pesca (tamaño y tipo de anzuelo, tamaño y material de la línea madre, dispositivos sonoros, tamaño y material de la brazolada, etc) o variables medioambientales (temperatura de la superficie del mar, condiciones climatológicas, viento) para la pesquería de palangre de Estados Unidos. El índice estandarizado fue obtenido utilizando Modelos Lineales Mixtos Generalizados bajo un enfoque de modelo delta-lognormal.

KEYWORDS

Catch/effort, abundance, Longlining, Fish catch statistics, By catch, logbooks, Multivariate analyses

INTRODUCTION

Information on the relative abundance of blue marlin (*Makaira nigricans*) and white marlin (*Tetrapturus albidus*) is necessary to tune stock assessment models. Data collected from the US longline fleet has been used to develop standardized catch per unit of effort (CPUE) indices of abundance for billfish (Cramer 1998). This report documents the analytical methods applied to the available US longline fleet data through 1999 and presents correspondent standardized CPUE indices for blue and white marlin. Catch in numbers and effort data were obtained from the Pelagic Longline Logbook reports data, while size information was gathered from the Pelagic Observer Program for Billfish. The US longline fleet operates over a wide geographical range of the western North Atlantic Ocean and although blue and white marlin are not now targeted nor landed by the US fleet, this bycatch constitutes a component of fishery mortality on these stocks that can be quantified.

MATERIALS AND METHODS

Hoey and Bertolino (1988) described the main features of the fleet and numerous authors (Hoey *et al*. 1989, Scott *et al*. 1993, Cramer and Bertolino 1998, Ortiz *et al*. 2000) have reviewed the available catch and effort data from the US Pelagic Longline fishery. Standardized catch rate indices were previously estimated for the 1996 stock assessment using Generalized Linear Models (GLM) with a delta-lognormal approach (Cramer 1998). The present report updates the catch and effort information through 1999 and includes analyses of variability associated with random factor interactions particularly for interactions that include the *Year* effect, following the suggestion of the statistics and methods working group of the SCRS in 1999.

Logbook records from the US Longline Pelagic fleet have been collected since 1986. From 1986 to 1991, submission of logbooks was voluntary, and thereafter, submission of logbook reports became mandatory. Swordfish, yellowfin, and other tunas are the main target species for the US Pelagic Longline fleet. Marlins are not retained by the U.S. fleet, although catch records of these and other by-catch species are recorded on logbooks. Since 1992, trained observers have recorded detailed information on gear characteristics, fishing operations as well morphometric and biological information from a target sub-sample level of 5% of the US longline Pelagic effort (Lee and Brown 1998). These constitute the Pelagic Observer Program (POP) data, which provide size and weight information on marlins caught by longline operations. The POP data collects substantially more detailed fishing information, which permits evaluation of relationships between marlins catch rates and additional factors, such as environmental (e.g. sea surface temperature, wind direction and intensity, and general weather conditions), gear configurations and characteristics (main line type and length; gangion type and length; hook type, size, and density per unit of main line; floats number and density; rattlers; light sticks; surface light-bouys; etc), and fishing operations (bait type, condition, and number; depth of set; soaking time; etc.).

The Pelagic Longline Logbook data comprises a total of 194,480 record-sets from 1986 through 1999. Each record contains information of catch by set, including: date and time, geographical location, catch in numbers of targeted and bycatch species, and fishing effort (as number of hooks per set). Of these trips, blue marlin were reported as being caught in 18,276 sets (9.4%) and white marlin in 17,759 sets (9.1%). Figures 1 and 2 show the geographical distribution of mean nominal CPUE (numbers of fish per thousand hooks) by 5° latitude-longitude grouping, and for three time periods; 1986 to 1990, 1991-1995, and 1996-1999. Comparatively, Figure 3 shows the mean total number of hooks reported (i.e. fishing effort) per set for the same strata. It is clear that fishing effort increased since 1986-90 in almost all fishing areas.

Logbooks only record numbers of fish. As per the recommendation of the SCRS Billfish Species Group, indices of abundance should be reported both in weight and numbers of fish, when possible. In order to convert number of fish to weight, size information on blue and white marlin caught by the US longline fleet was retrieved from the POP. The POP covers about 5% of the total annual U.S. Atlantic pelagic longline trips, but POP data are available only since 1992. Figures 4 and 5 show the size-frequency distribution for blue marlin and white marlin, respectively, from POP data and their respective mean and standard deviation by year. The number of fish measured was considered as being too small to estimate mean size in strata smaller than the year average. Conversion from mean annual size to weight used the current size-weight relationships for combined sex (Prager *et al*. 1995). For years prior to 1992, the mean size value from 1992 was applied. For both blue and white marlin there is not any clear trend in the mean size of measured fish from 1992 to 1999.

The longline fishing grounds for the US fleet extend from the Grand Banks in the North Atlantic to latitudes of 5-10° south, off the South American coast, including the Caribbean Sea and the Gulf of Mexico. Eight geographical areas of longline fishing were used for classification (Fig. 6). These include the Caribbean (CAR, area 1), Gulf of Mexico (GOM, area 2), Florida East coast (FEC, area 3), South Atlantic Bight (SAB, area 4), Mid-Atlantic Bight (MAB, area 5), New England coastal (NEC, area 6), Northeast distant waters (NED, or Grand Banks, area 7), the Sargasso Sea and the North central Atlantic (SNA, area 8) and Southern Offshore (OFS, area 10, ranging to 5°N latitude). Calendar quarters were used to account for seasonal fishery distribution through the year (Jan-Mar, Apr-Jun, Jul-Sep, and Oct-Dec). Other factors included in the analyses of catch rates included the use of light-sticks and the density of light-sticks, the type of bait (alive or dead), and a variable named operations procedure (OP), which is a categorical classification of US longline vessels based on their fishing configuration, type and size of the vessel, and main target species and area of operation(s). This variable has been shown to be significantly important as a predictor in the analyses of swordfish catch rates (Ortiz *et al*. 2000).

Fishing effort is reported in terms of the total number of hooks per trip and number of sets per trip. As number of hooks per set vary, catch rates were calculated as number of marlin caught per 1000 hooks. The longline fleet targets mainly swordfish and yellowfin tuna, but other tuna species are also targets including bigeye tuna and albacore (to a lesser extent, some of the trips-sets target other pelagic species including sharks, dolphin and small tunas). A target variable was defined based on the proportion of the number of swordfish caught to the total number of fish per set, with four discrete target categories corresponding to the ranges 0-25%, 25-50%, 50-75%, and 75-100%. As marlins are not targeted species by the US longline fleet, this measure of targeting was investigated to allow evaluation of targeting towards swordfish or tunas.

As mentioned previously, the Pelagic Observer Program samples about 5% of the US longline fleet trips but collects significantly more detailed information compared with the logbook reports. This information includes specifics of gear configurations such as main line material, size, diameter, total length; hook type, size, and brand; light-sticks number and color; gangion size, material and length; leader material and size; rattlers; number and type of floats; number of hooks between floats; number of surface lights. Also, specifics about fishing configuration such as depth of the float-line, soak time, intended targeted species, bait type and number/weight of bait per set are recorded.

Some general environmental information such as sea surface temperature at the beginning and end of the set and haul retrieval, wind speed and direction, estimated depth of hooks, bottom depth and general weather condition (calm, storm, rain/snow, etc) are also recorded. The POP data includes 4,026 record-sets from 1992 through 1999. Of these, 720 sets caught blue marlin and 974 caught white marlin. An exploratory analysis of the relationship between catch rates for blue and white marlin with several gear, fishing and environmental factors was performed to identify other potentially significant effects that could account for variability of catch rates for these species, not consider in the PLL analysis. For continuos variables (sea surface temperature, depth, main length, density of light-sticks per hook, density of hooks per unit of main line, gangion length, and distance between gangions) General Additive Models (GAMs) were used to analyze the relative influence of various factors on catch rates for blue and white marlin (Bigelow *et al* 1999, Kleiber and Bartoo 1998). GAMs are non-parametric generalizations of multiple linear regression and are less restrictive in assumptions about the underlying statistical distribution of the data (Hastie and Tibshirani, 1990). Nonlinear effects were fitted with a locally-weighted polynomial scatterplot smoother (loess smother) using the S-Plus software package (Venables and Ripley 1997). Because of the high percent of zero observations, GAMs analyses were restricted to positive trips for both species. GAM-derived effects for each factor were then plotted and the relative magnitude of each effect was judged by the relative y-axis ranges of the loess function (the greater the y-axis range, the larger the deviance explained by the factor considered, see Bigelow *et al.* 1999). Significant effects were then converted from continuos variables into categorized factors so they could be incorporated into a delta-lognormal Generalized Linear Modeling (GLM) analysis. Levels within factors were chosen based on the loess-derived plots.

For the PLL data, relative indices of abundance for blue and white marlin were estimated by a GLM approach assuming a delta-lognormal model distribution. The delta model fits separately the proportion of positive sets assuming a binomial error distribution and the mean catch rate of sets where at least one marlin was caught assuming a lognormal error distribution. The standardized index is the product of these model-estimated components. The log-transformed frequency distributions for blue and white marlin are shown in Figure 7. The estimated proportion of successful sets per stratum is assumed to be the result of *r* positive sets of a total *n* number of sets, and each one is an independent Bernoulli-type realization. The estimated proportion is a linear function of fixed effects and interactions. The probit function was used as a link between the linear factor component and the binomial error. For sets that caught at least one marlin ("positive" observations), estimated CPUE rates were assumed to follow a lognormal error distribution (lnCPUE) of a linear function of fixed factors and random effect interactions, particularly when the *Year* effect was within the interaction.

For the pelagic observer program data, relative indices of abundance for blue and white marlin were estimated by a GLM approach also assuming a delta lognormal distribution. For these data, the following factors were included in the analysis: year, area, OP (operations procedure), target species (as specified by the captain prior to the set), season (quarterly months), *light-sticks* (0, 0-0.75, and > 0.75 light-sticks per hook), hook density, rattlers, surface lights, main line material (1=nylon, 2=others), hook manufacture (three categories), hook type (circle hooks, J-type hooks, and unknown), hook size (7/0-10/0, 11/0-16/0, and unknown), weather condition (Clear/cloudy, Rain/snow, Severe, Unknown), distance between gangions (< 180 ft, = 180 ft), main line length (< 30 NM, = 30 NM), bait kind (including mackerel, herring, squid, sardine, scad, artificial lures, unknown, and several mixed combination of these types), and bait type (classifying sets as live bait only, dead bait, and mixed).

A step-wise regression procedure was used to determine the set of systematic factors and interactions that significantly explained the observed variability. Because the difference of deviance between two consecutive (nested) models follows a $?^2$ (Chi-square) distribution, this statistic was used to test for the significance of an additional factor in the model. The number of additional parameters associated with the added factor minus one corresponds to the number of degrees of freedom in the $?^2$ test (McCullagh and Nelder, 1989 pp 393). Deviance analysis tables are presented for both data series, each table includes the deviance for the proportion of positive observations (i.e. positive trips/total trips), and the deviance for the positive catch rates. Final selection of explanatory factors was conditional to a) the relative percent of deviance explained by adding the factor in evaluation (normally, factors that explained more than 5 or 10% were selected), b) the χ^2 test of significance, and c) the Type-III test significance within the final specified model.

Once a set of fixed factors was specified, possible interactions were evaluated, and in particular interactions between the *Year* effect and other factors. Selection of the final mixed model was based on the Akaike's Information Criterion (AIC), Schwarz's Bayesian Criterion (SBC), and a chi-square test of the difference between the [–2 loglikelihood statistic] between successive model formulations (Littell et al. 1996). Relative indices for the delta model formulation were calculated as the product of the year effect least square means (LSmeans) from the binomial and the lognormal model components. The LSmeans estimates use a weighted factor of the proportional observed margins in the input data to account for the un-balanced characteristics of the data. LSmeans of lognormal positive trips were bias-corrected using Lo et al. (1992) algorithms. Analyses were done using the GLIMMIX and MIXED procedures from the SAS? statistical computer software (SAS Institute Inc. 1997).

RESULTS AND DISCUSSION

The analyses of the Pelagic Observer Program data should be considered as an exploratory evaluation of relationships between catch rates of marlins and diverse factors associated to the fishing operations. A main restriction in this analysis is the low percentage of sets with positive marlin catch, which is characteristic of incidental catch species in the longline fishery. We opted to use the delta approach, thereby restricting the GAM analyses to positive catch set for blue and white marlin rather than add constant positive values to nominal CPUEs to avoid undefined logarithm transformation of zero CPUEs. Bigelow et al (1999) have also used GAMs to examine influence of various factors on catch rates of swordfish (target species) and blue shark (bycatch species) on the U.S. North Pacific longline fishery. They added a constant value to avoid zero CPUEs, but their percentage of zero observations was only 25% for blue shark, compared to the 82% and 75% that we have for blue and white marlin, respectively in the POP data. Therefore, in this study, the GAM analyses reflect the significance of factors with catch rates of blue and white marlin given that at least one fish is caught. The objective of conducting the GAM analyses was primarily to choose from a wide array of fishing conditions, gear specifications and environmental variables, those which were more significantly associated with blue and white marlin catch rates. Figure 8 shows the derived loess plots of blue marlin for several factors with the 95% confidence intervals, the relative density of points for different factor values is show by the rug plot on the x-axis. The relative magnitude of the effects of the explanatory variable is proportional to the range on the y-axis. An explanatory variable is typically non-significant if a horizontal line can be drawn within the 95% confidence band. The results show that main line length, distance between gangions, hook density and soak time have evident effects on catch rates for blue marlin. In contrast, wind speed, wave height, and sea surface temperature have no noticeable effects on blue marlin catch rates. We used these derived loess plots to categorize the continuos variables with significant effects, to incorporate these factor levels into a GLM delta model. Using the change of the slope, and minimum-maximun in the loess plots, we determined cut-off points for the continuous variables to use as level boundaries.

Tables 1 and 2 show the deviance analysis for blue and white marlin, respectively from the Pelagic Observer Program data analyses. For both, the proportion of positive sets and the catch rates of positive sets, only fixed factors were considered, as there were not enough degrees of freedom for evaluating interactions among factors. In the case of blue marlin, the fixed effects of area, season and kind of bait were the major factors that explained the probability of capture of at least one fish. For the mean catch rate on positive sets, the fixed effects of area, OP, bait kind, and main line length were more significant. For white marlin, the same factors: area, season, and bait kind were the main explanatory variables for the proportion of positive sets. For the mean catch rate, area, OP, light-sticks and main line length were significant factors. Once a set of fixed factors was selected, we evaluated first level random interaction between the year and other effects. Table 3 shows the results from the random test analyses, for both marlin species. The three model-selection criteria used showed agreement for the best model selection.

The deviance analyses of the Pelagic Longline Logbook data are show in Tables 4 and 5. For blue marlin, the proportion of positive sets was explained by the area, season, target2, and the interaction of year*area, year*OP and area*season. The mean catch rate for sets with blue marlin catch was best explained by the main effects of area, OP, and light-sticks plus the interactions year*area, year*OP, area*OP and year*light sticks. For white marlin, the proportion of positive sets was explained by the area, OP, season, target2, and the interaction of year*area, year*OP, area*OP and area*season. The mean catch rate for sets with white marlin catch was explained by the area, OP, light-sticks main effects and the interactions year*area, year*OP, area*OP and area*season. All interactions that included the year factor were treated as random interactions. Table 6 shows the results of the mixed model (fixed factors and random interactions) and the information criteria used for evaluation.

The comparison of the model results from the Observer Program and the Longline Logbook data show that for blue marlin the proportion of positive sets is best explained by the main factors: area, season, OP and target2. The Observer data suggest that bait kind is also an explanatory variable, however it is possible that this factor is confounded with the target2, as the selection of bait is determined by the species targeted. In the case of positive sets, the main factors of area, OP, and light-sticks were most important in the PLL data. The Observer data suggest that the length of the longline is also correlated with catch rates. The derived loess plot for main line length shows that in general there is an inverse relationship between blue marlin catch rate and longline length (shorter lengths yield higher catch rates). Most of the observations are between 10 and 40 nautical miles of longline, from 10 to 30 NM the relationship is decreasing linearly, for 30 and above, it appears that there is a change in the slope, with the relationship becoming more stable. For white marlin, in the proportion of positive sets PLL analysis, the main factors were area, season, OP and target2 (similar to the blue marlin analysis). Also, the observer data suggest the use of bait kind as explanatory variable. For the catch rate of white marlin on positive sets in the PLL data, area, season, OP and target2 were the main factors. The observer data indicated that longline length and light-sticks are also important explanatory factors.

Standardized CPUE series for blue and white marlin are shown in Tables 7 and 8 and in Figures 9 and 10. Coefficients of variation for the blue marlin analysis of the PLL data range from 19.5% to 24.7%. For white marlin, the standardized series are shown in Figure 9; coefficients of variation range from 22.2 to 26.5%. We also plotted the estimated CPUE series from the observer data and compared it with the corresponding pattern from the Logbook data (Figs. 11 and 12). Overall, both series agreed for blue and white marlin, with slightly large confidence intervals for the Observer's CPUE series.

For comparison, standardized CPUE series were also estimated using number of fish per thousand hooks as dependent variable in the Pelagic Longline Logbook dataset. Model formulations were exactly the same as the final models for the weight analyses in terms of explanatory variables and interactions. Tables 9-10, and Figure 13 show the standardized CPUE series for blue and white marlin, respectively. Overall, the trends were similar to the ones observed in the weight CPUE series. In order to have a more valid comparison, both weight and number of fish CPUE series were normalized (i.e. each value minus the mean of the time series and divided by the standard deviation of the series) to a mean zero and one standard deviation. Figure 14 shows the normalized plots for blue and white marlin CPUE series. For blue marlin, the weight-based and number-based CPUE series follow similar trends, the major difference between the series occurring in 1996. In contrast, for white marlin, there were not differences between the number-based and weight-based standardized CPUE series. For white marlin, this result reflects the almost no change in the mean size of white marlin from 1992 to 1999 (Fig. 5, right panel). In the case of blue marlin, 1996 is the highest mean size observed from the measured fish (Fig. 4, right panel).

LITERATURE CITED

BIGELOW, K.A., C.H. Boggs, and X. He. 1999. Environmental effects on swordfish and blue shark catch rates in the US North Pacific longline fishery. Fish. Oceanogr. 8(3): 178-198.

CRAMER, J. 1998. Large Pelagic Logbook catch rate indices for Billfish. Col. Vol. Sci. Pap. ICCAT, 47:301-307.

CRAMER, J. and A. Bertolino. 1998. Standardized catch rates for swordfish (*Xiphias gladius*) from the U.S. longline fleet through 1997. Col. Vol. Sci. Pap. ICCAT, 49(1):449-456.

HASTIE, T. J. and R. J. Tibshirani. 1990. Generalized Additive Models. London: Chapman and Hall, 335 pp.

HOEY, J.J. and A. Bertolino. 1988. Review of the U.S. fishery for swordfish, 1978 to 1986. Col. Vol. Sci. Pap. ICCAT, 27:256-266.

HOEY, J.J., R. Conser and E. Duffie. 1989. Catch per unit effort information from the U.S. swordfish fishery. Col. Vol. Sci. Pap. ICCAT, 39:195-249.

KLEIBER, P. and N. Bartoo. 1998. Standardizing swordfish, *Xiphias gladius*, Longline catch per unit of effort using General Additive Models. Pages 181-193 *in* NOAA Tech. Rep. NMFS 142: Biology and Fisheries of Swordfish *Xiphias gladius*. Papers from the International Symposium on Pacific swordfish, Ensenada, Mexico, Dec. 1994.

LEE, D.W. and C.J. Brown. 1998. SEFSC Pelagic Observer Program Data Summary for 1992-1996. NOAA Tech. Memo. NMFS-SEFSC-408, 21 pp.

LITTELL, R.C., G.A. Milliken, W.W. Stroup, and R.D Wolfinger. 1996. SAS® System for Mixed Models, Cary NC, USA:SAS Institute Inc., 1996. 663 pp.

LO, N.C., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49: 2515-2526.

MCCULLAGH, P. and J.A. Nelder. 1989. Generalized Linear Models 2nd edition. Chapman & Hall.

ORTIZ, M. J. Cramer, A. Bertolino and G. P. Scott. 2000. Standardized catch rates by sex and age for swordfish (*Xiphias gladius*) from the U.S. Longline Fleet 1981-1998. Col. Vol. Sci. Pap. ICCAT, 51: 1559-1620..

PRAGER, M.H., E. D. Prince and D. W. Lee. 1995. Empirical length and weight conversion equation: for blue marlin, white marlin, and sailfish from the North Atlantic Ocean. Bull of Mar. Sci. 56(1):201-210.

SAS Institute Inc. 1997, SAS/STAT® Software: Changes and Enhancements through Release 6.12. Cary, NC, USA:Sas Institute Inc., 1997. 1167 pp.

SCOTT, G. P., V. R. Restrepo and A. R. Bertolino. 1993. Standardized catch rates for swordfish (*Xiphias gladius*) from the US longline fleet through 1991. Col. Vol. Sci. Pap. ICCAT, 40(1):458-467.

VENABLES, W. N. and B. D. Ripley. 1997. Modern Applied Statistics with S-Plus 2nd edition. Springer Statistics and Computing series.

Table 1. Deviance analysis table of explanatory variables in the delta lognormal model for blue marlin catch rates from the Observer Pelagic Program data. Percent of total deviance refers to the deviance explained by the full model; *p* value refers to the 5% Chi-square probability between consecutive models.

Model factors positive catch rates values	d. f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	334.21			
YEAR	7	313.68	20.5	12.4%	0.005
… + AREA	10	252.53	61.1	36.8%	< 0.001
… + OP	7	218.31	34.2	20.6%	< 0.001
… + TARGETSP	4	217.42	0.9	0.5%	0.926
… + SEASON	3	211.77	5.6	3.4%	0.130
… + LGHTC	2	205.54	6.2	3.7%	0.044
… + HKDENC	2	198.53	7.0	4.2%	0.030
… + RATLR	1	198.53	0.0	0.0%	0.977
… + SRFLITE	1	197.12	1.4	0.9%	0.235
… + MAINMAT	1	196.84	0.3	0.2%	0.595
… + HKBRAND	3	196.51	0.3	0.2%	0.954
… + HKTYPE	2	195.21	1.3	0.8%	0.524
… + HKSIZE	2	194.36	0.9	0.5%	0.652
… + WEATHERC	3	194.23	0.1	0.1%	0.989
… + GANGDISC	1	194.22	0.0	0.0%	0.914
… + MAINLENC	1	182.75	11.5	6.9%	< 0.001
… + BAITKND	16	168.86	13.9	8.4%	0.607
… + BAIT	2	167.98	0.9	0.5%	0.643

Model factors proportion positive catch rates values	d. f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	3780.25			
YEAR	7	3764.63	15.6	2.9%	0.029
… + AREA	10	3493.02	271.6	50.0%	< 0.001
… + OP	7	3477.14	15.9	2.9%	0.026
… + SEASON	3	3341.62	135.5	24.9%	< 0.001
… + LGHTC	3	3334.29	7.3	1.3%	0.062
… + TARGETSP	4	3331.63	2.7	0.5%	0.616
… + RATLR	1	3331.44	0.2	0.0%	0.656
… + SRFLITE	1	3331.43	0.0	0.0%	0.938
… + HKBRAND	3	3323.44	8.0	1.5%	0.046
… + HKTYPE	2	3322.61	0.8	0.2%	0.660
… + WEATHERC	3	3320.63	2.0	0.4%	0.577
… + GEARCND	5	3310.82	9.8	1.8%	0.081
… + BAIT	2	3297.46	13.4	2.5%	0.001
… + BAITKND	18	3239.25	58.2	10.7%	< 0.001
… + MAINLENC	1	3238.61	0.6	0.1%	0.425
… + GANGDISC	1	3238.39	0.2	0.0%	0.635
… + XHKDEPC	1	3238.03	0.4	0.1%	0.552
… + HKDENC	2	3236.92	1.1	0.2%	0.575

Table 2. Deviance analysis table of explanatory variables in the delta lognormal model for white marlin catch rates from the Observer Pelagic Program data. Percent of total deviance refers to the deviance explained by the full model, p value refers to the 5% Chi-square probability between consecutive models.

Model factors positive catch rates values	d. f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	481.90			
YEAR	7	470.78	11.1	6.9%	0.133
… + AREA	10	398.13	72.6	44.8%	< 0.001
… + OP	7	385.46	12.7	7.8%	0.081
… + TARGETSP	4	384.53	0.9	0.6%	0.920
… + SEASON	3	378.97	5.6	3.4%	0.135
… + LGHTC	3	368.97	10.0	6.2%	0.019
… + HKDENC	2	361.05	7.9	4.9%	0.019
… + RATLR	1	360.74	0.3	0.2%	0.581
… + SRFLITE	1	358.48	2.3	1.4%	0.132
… + MAINMAT	1	357.70	0.8	0.5%	0.377
… + HKBRAND	3	352.02	5.7	3.5%	0.129
… + HKTYPE	2	349.25	2.8	1.7%	0.250
… + HKSIZE	2	347.84	1.4	0.9%	0.495
… + WEATHERC	3	343.64	4.2	2.6%	0.240
… + GANGDISC	1	342.42	1.2	0.7%	0.271
… + MAINLENC	1	331.85	10.6	6.5%	0.001
… + BAITKND	16	321.04	10.8	6.7%	0.821
… + BAIT	2	319.60	1.4	0.9%	0.486

Model factors proportion positive catch rates values	d. f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	4455.10			
YEAR	7	4424.09	31.0	4.7%	< 0.001
… + AREA	10	4215.78	208.3	31.8%	< 0.001
… + OP	7	4205.78	10.0	1.5%	0.189
… + TARGETSP	4	4200.18	5.6	0.9%	0.231
… + SEASON	3	3953.82	246.4	37.7%	< 0.001
… + LGHTC	3	3933.72	20.1	3.1%	< 0.001
… + HKDENC	2	3932.65	1.1	0.2%	0.586
… + RATLR	1	3932.53	0.1	0.0%	0.733
… + SRFLITE	1	3915.38	17.1	2.6%	< 0.001
… + MAINMAT	1	3904.42	11.0	1.7%	< 0.001
… + HKBRAND	3	3892.43	12.0	1.8%	0.007
… + HKTYPE	2	3879.57	12.9	2.0%	0.002
… + HKSIZE	2	3878.12	1.5	0.2%	0.482
… + WEATHERC	3	3870.72	7.4	1.1%	0.060
… + GANGDISC	1	3868.13	2.6	0.4%	0.107
… + MAINLENC	1	3858.75	9.4	1.4%	0.002
… + BAITKND	18	3801.54	57.2	8.7%	< 0.001
… + BAIT	2	3801.05	0.5	0.1%	0.785

Table 3. Analyses of delta lognormal mixed model formulations for blue and white marlin catch rates from the Observer Pelagic Program data. Likelihood ratio tests the difference of –2 REM log likelihood between two nested models. ***** indicates the selected model for each component of the final delta mixed model.

	Blue Marlin Generalized Linear Mixed Models	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
	Proportion Positives					
	Year Area Season Baitknd	1151.697	-576.848	-578.861		
	Year Area Season Baitknd Year*Area	1145.042	-574.521	-578.547	6.655	0.0099
	Year Area Season Baitknd Year*Area Year*Season	1137.632	-571.816	-571.855	7.41	0.0065
*	Year Area Season Baitknd Year*Area Year*Season Area*Season	1114.189	-561.094	-569.146	23.443	0.0000
	Positive Catch					
	Year Area OP Mainlength	1236.343	-619.172	-621.443		
	Year Area OP Mainlength Year*Area	1231.999	-618.000	-622.542	4.344	0.0371
*	Year Area OP Mainlength Year*Area Year*OP	1214.765	-610.382	-617.196	17.234	0.0000

	White Marlin Generalized Linear Mixed Models	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
	Proportion Positives					
	Year Area Season Baitknd	1296.098	-649.049	-651.065		
	Year Area Season Baitknd Year*Area	1296.098	-650.049	-654.082	0	1.0000
	Year Area Season Baitknd Year*Area Year*Season	1295.686	-650.843	-656.893	0.412	0.5210
	Year Area Season Baitknd Year*Area Year*Season Area*Season	1266.281	-637.141	-645.207	29.405	0.0000
*	Year Area Season Baitknd Year*Area Year*Season Area*Season	1266.281	-636.141	-642.190	0	1.0000
	Positive Catch					
	Year Area OP Lights Mainlen	1898.878	-950.439	-952.865		
	Year Area OP Lights Mainlen Year*Area	1872.442	-938.221	-943.072	26.436	0.0000
*	Year Area OP Lights Mainlen Year*Area Year*OP	1863.458	-934.729	-942.006	8.984	0.0027
	Year Area OP Lights Mainlen Year*Area Year*OP Year*Mainlen	1863.435	-935.717	-945.42	0.023	0.8795

Table 4. Deviance analysis table of explanatory variables in the delta lognormal model for blue marlin catch rates from the Pelagic Longline Logbook data. Percent of total deviance refers to the deviance explained by the full model; *p* value refers to the 5% Chi-square probability between nested models.

Model factors positive catch rates values	d. f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	0	7941.05			
YEAR	13	7706.23	234.8	11.3%	< 0.001
YEAR AREA	8	6645.14	1061.1	50.9%	< 0.001
YEAR AREA SEASON	3	6566.23	78.9	3.8%	< 0.001
YEAR AREA SEASON OP	10	6268.01	298.2	14.3%	< 0.001
YEAR AREA SEASON OP TARG2	3	6257.42	10.6	0.5%	0.014
YEAR AREA SEASON OP TARG2 LGHTC	3	6154.92	102.5	4.9%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY	2	6097.41	57.5	2.8%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*BAIT	20	6031.39	66.0	3.2%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*TARG	39	6027.12	70.3	3.4%	0.002
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*SEAS	37	6025.95	71.5	3.4%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY AREA*SEAS	22	6002.61	94.8	4.5%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*LGHT	39	5987.87	109.5	5.3%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY AREA*OP	57	5935.55	161.9	7.8%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*OP	103	5874.77	222.6	10.7%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*AREA	101	5854.96	242.4	11.6%	< 0.001

Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1		121218.6			
YEAR	13	120770.7	447.9	2.9%	< 0.001
YEAR AREA	8	112230.2	8540.5	54.3%	< 0.001
YEAR AREA SEASON	3	110931.8	1298.4	8.3%	< 0.001
YEAR AREA SEASON OP	11	110568.1	363.7	2.3%	< 0.001
YEAR AREA SEASON OP TARG2	3	107336.2	3231.9	20.6%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC	3	107110.7	225.6	1.4%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY	2	107017.5	93.2	0.6%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*BAIT	21	106842.2	175.2	1.1%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*TARG	39	106681.4	336.0	2.1%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*SEAS	38	106677.2	340.3	2.2%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*LGHT	39	106671.7	345.7	2.2%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY AREA*OP	69	106375.2	642.3	4.1%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY AREA*SEAS	24	106166.2	851.2	5.4%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*OP	110	106043.9	973.5	6.2%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*AREA	103	105503.5	1514.0	9.6%	< 0.001

Table 5. Deviance analysis table of explanatory variables in the delta lognormal model for white marlin catch rates from the Pelagic Longline Logbook data. Percent of total deviance refers to the deviance explained by the full model; *p* value refers to the 5% Chi-square probability between nested models.

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	0	7743.3			
YEAR	13	7374.6	368.6	25.8%	< 0.001
YEAR AREA	8	6935.9	438.7	30.8%	< 0.001
YEAR AREA SEASON	3	6868.0	68.0	4.8%	< 0.001
YEAR AREA SEASON OP	10	6659.3	208.7	14.6%	< 0.001
YEAR AREA SEASON OP TARG2	3	6657.6	1.7	0.1%	0.631
YEAR AREA SEASON OP TARG2 LGHTC	3	6528.7	128.9	9.0%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY	2	6478.8	49.9	3.5%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*SEAS	37	6442.5	36.3	2.5%	0.502
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*TARG	39	6442.1	36.6	2.6%	0.578
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*BAIT	20	6431.3	47.5	3.3%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*LGHT	39	6430.2	48.6	3.4%	0.139
YEAR AREA SEASON OP TARG2 LGHTC BAITTY AREA*SEAS	24	6403.7	75.1	5.3%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*AREA	101	6367.0	111.8	7.8%	0.218
YEAR AREA SEASON OP TARG2 LGHTC BAITTY AREA*OP	56	6346.3	132.5	9.3%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*OP	104	6317.0	161.7	11.3%	< 0.001

Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1		118854.7			
YEAR	13	118467.7	387.0	3.1%	< 0.001
YEAR AREA	8	114831.7	3636.0	29.3%	< 0.001
YEAR AREA SEASON	3	112649.9	2181.7	17.6%	< 0.001
YEAR AREA SEASON OP	11	111788.7	861.2	6.9%	< 0.001
YEAR AREA SEASON OP TARG2	3	108605.4	3183.4	25.6%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC	3	108553.5	51.9	0.4%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY	2	108536.7	16.8	0.1%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*TARG	39	108414.9	121.8	1.0%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*BAIT	21	108384.2	152.5	1.2%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*LGHT	39	108351.1	185.6	1.5%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*SEAS	38	108180.5	356.2	2.9%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY AREA*OP	69	107588.1	948.6	7.6%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*OP	110	107307.3	1229.4	9.9%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY YEAR*AREA	103	107248.3	1288.4	10.4%	< 0.001
YEAR AREA SEASON OP TARG2 LGHTC BAITTY AREA*SEAS	24	106437.6	2099.1	16.9%	< 0.001

Table 6. Analyses of delta lognormal mixed model formulations for blue and white marlin catch rates from the Pelagic Longline Logbook data. Likelihood ratio tests the difference of -2 REM log likelihood between two nested models. * indicates the selected model for each component of the delta mixed model.

	Blue Marlin Generalized Linear Mixed Models	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
	Proportion Positives					
	Year Area Season OP Targ2	18601.27	-9301.63	-9305.02		
	Year Area Season OP Targ2 *Year*Area*	18323.84	-9163.92	-9170.69	277.43	0.0000
*	Year Area Season OP Targ2 *Year*Area Year*OP*	18301.64	-9153.82	-9163.98	22.2	0.0000
	Year Area Season OP Targ2 *Year*Area Year*OP Area*Season*	18474.44	-9241.22	-9254.76	-172.8	N/A
	Positive Catch					
	Year Area OP Lights	32509.16	-16255.6	-16259.5		
	Year Area OP Lights Year*Area	32043.39	-16023.7	-16031.5	465.77	0.0000
	Year Area OP Lights Year*Area Year*OP	31808.87	-15907.4	-15919.2	234.52	0.0000
	Year Area OP Lights Year*Area Year*OP Area*OP	31603.93	-15806	-15821.6	204.94	0.0000
*	Year Area OP Lights Year*Area Year*OP Area*OP Year*Lights	31398.63	-15704.3	-15723.8	205.3	0.0000

	White Marlin Generalized Linear Mixed Models	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
	Proportion Positives					
	Year Area Season OP Targ2	20860.79	-10431.4	-10434.8		
	Year Area Season OP Targ2 *Year*Area*	20050.06	-10027	-10033.8	810.73	0.0000
	Year Area Season OP Targ2 *Year*Area Year*OP*	19612.37	-9809.19	-9819.34	437.69	0.0000
	Year Area Season OP Targ2 *Year*Area Year*OP Area*Season*	18960.69	-9484.35	-9497.89	651.68	0.0000
*	Year Area Season OP Targ2 *Year*Area Year*OP Area*Season Area*OP*	18684.69	-9347.34	-9364.69	276	0.0000
	Positive Catch					
	Year Area Season OP Targ2	32880.02	-16441	-16444.9		
	Year Area Season OP Targ2 *Year*Area*	32772.66	-16388.3	-16396.1	107.36	0.0000
	Year Area Season OP Targ2 *Year*Area Year*OP*	32644.64	-16325.3	-16337	128.02	0.0000
	Year Area Season OP Targ2 *Year*Area Year*OP Area*Season*	32546.82	-16277.4	-16293	97.82	0.0000
*	Year Area Season OP Targ2 *Year*Area Year*OP Area*Season Area*OP*	32360.2	-16185.1	-16204.6	186.62	0.0000

Table 7. Nominal and standardized (Delta lognormal mixed model) CPUE series (kg fish/1000 hooks) for the Pelagic longline blue marlin catch in the western Atlantic. The index column is the scaled to a maximum of standardized CPUE series.

Year	Nominal CPUE	Standard CPUE	Coeff Var	Std Error	Index	Upp CI 95%	Low CI 95%
1986	21.22	29.43	0.248	7.28	1.00	1.63	0.61
1987	19.06	20.35	0.209	4.26	0.69	1.05	0.46
1988	19.40	19.24	0.212	4.09	0.65	1.00	0.43
1989	19.42	23.37	0.197	4.61	0.79	1.17	0.54
1990	18.72	23.50	0.201	4.71	0.80	1.19	0.54
1991	15.99	16.96	0.212	3.60	0.58	0.88	0.38
1992	18.86	22.71	0.198	4.49	0.77	1.14	0.52
1993	25.81	26.85	0.195	5.24	0.91	1.34	0.62
1994	23.41	22.78	0.208	4.73	0.77	1.17	0.51
1995	23.15	18.99	0.216	4.11	0.65	0.99	0.42
1996	26.36	19.69	0.221	4.36	0.67	1.04	0.43
1997	18.52	13.87	0.230	3.19	0.47	0.74	0.30
1998	11.36	11.95	0.233	2.78	0.41	0.64	0.26
1999	10.87	12.38	0.238	2.94	0.42	0.67	0.26

Table 8. Nominal and standardized (Delta lognormal mixed model) CPUE series (kg fish/1000 hooks) for the Pelagic longline white marlin catch in the Western Atlantic. The index column is the scaled to a maximum of standardized CPUE series.

Year	Nominal CPUE	Standard CPUE	Coeff Var	Std Error	Index	Upp CI 95%	Low CI 95%
1986	11.98	13.94	0.249	3.473	1.00	1.63	0.61
1987	7.76	6.21	0.236	1.463	0.45	0.71	0.28
1988	6.01	5.54	0.245	1.356	0.40	0.64	0.25
1989	6.45	7.17	0.228	1.633	0.51	0.81	0.33
1990	5.46	5.45	0.242	1.318	0.39	0.63	0.24
1991	5.84	5.53	0.242	1.340	0.40	0.64	0.25
1992	6.66	7.12	0.223	1.585	0.51	0.79	0.33
1993	6.27	5.11	0.234	1.194	0.37	0.58	0.23
1994	6.30	4.89	0.249	1.217	0.35	0.57	0.21
1995	6.19	3.72	0.255	0.948	0.27	0.44	0.16
1996	4.92	3.25	0.266	0.862	0.23	0.39	0.14
1997	4.87	3.36	0.264	0.890	0.24	0.41	0.14
1998	4.05	3.87	0.260	1.005	0.28	0.46	0.17
1999	5.19	4.86	0.255	1.242	0.35	0.58	0.21

Table 9. Nominal and standardized (delta lognormal mixed model) CPUE series (fish/ 1000 hooks) of blue marlin from the US Pelagic longline fishery. The index column is the scaled to a maximum of the standardized CPUE series.

Year	Nominal	Standardized	Coeff Var	Index	95% confidence intervals	
1986	0.497	0.689	28.9%	1.000	1.763	0.567
1987	0.446	0.476	25.8%	0.691	1.150	0.416
1988	0.454	0.450	26.4%	0.654	1.099	0.389
1989	0.455	0.547	23.9%	0.794	1.272	0.496
1990	0.438	0.550	24.2%	0.799	1.287	0.495
1991	0.374	0.397	27.0%	0.576	0.980	0.339
1992	0.442	0.532	24.0%	0.772	1.240	0.481
1993	0.478	0.497	24.0%	0.722	1.159	0.449
1994	0.414	0.403	26.4%	0.585	0.982	0.348
1995	0.340	0.279	29.5%	0.405	0.722	0.227
1996	0.350	0.262	30.6%	0.380	0.690	0.209
1997	0.270	0.202	33.8%	0.294	0.567	0.152
1998	0.189	0.199	34.3%	0.289	0.562	0.148
1999	0.179	0.203	34.7%	0.295	0.579	0.150

Table 10. Nominal and standardized (delta lognormal mixed model) CPUE series (fish/ 1000 hooks) of white marlin from the US Pelagic longline fishery. The index column is the scaled to a maximum of the standardized CPUE series.

Year	Nominal	Standardized	Coeff Var	Index	95% confidence intervals	
1986	11.984	13.938	24.9%	1.000	1.634	0.612
1987	7.756	6.210	23.6%	0.446	0.709	0.280
1988	6.007	5.538	24.5%	0.397	0.644	0.245
1989	6.452	7.170	22.8%	0.514	0.807	0.328
1990	5.460	5.446	24.2%	0.391	0.630	0.242
1991	5.837	5.526	24.2%	0.396	0.639	0.246
1992	6.660	7.123	22.3%	0.511	0.793	0.329
1993	6.273	5.112	23.4%	0.367	0.582	0.231
1994	6.299	4.888	24.9%	0.351	0.573	0.215
1995	6.190	3.719	25.5%	0.267	0.441	0.162
1996	4.920	3.246	26.6%	0.233	0.393	0.138
1997	4.871	3.365	26.4%	0.241	0.406	0.144
1998	4.047	3.874	26.0%	0.278	0.463	0.167
1999	5.190	4.864	25.5%	0.349	0.577	0.211

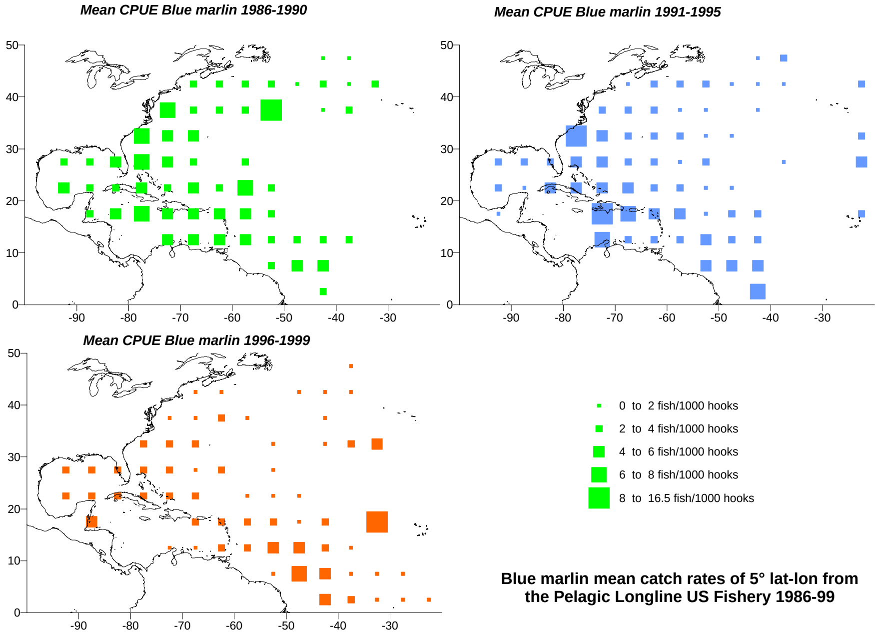


Figure 1. Mean nominal CPUE (fish/1000 hooks) for blue marlin catch from the Pelagic Longline US fishery on 5° lat-lon grids

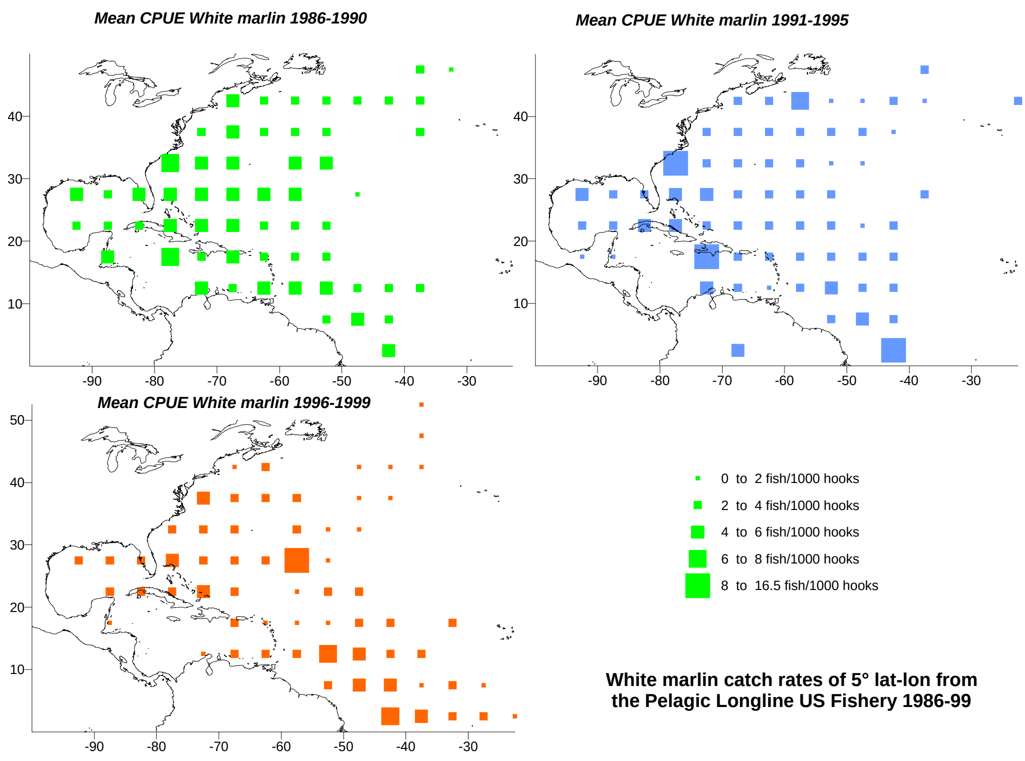


Figure 2. Mean nominal CPUE (fish/1000 hooks) for white marlin catch from the Pelagic Longline US fishery on 5° lat-lon grids

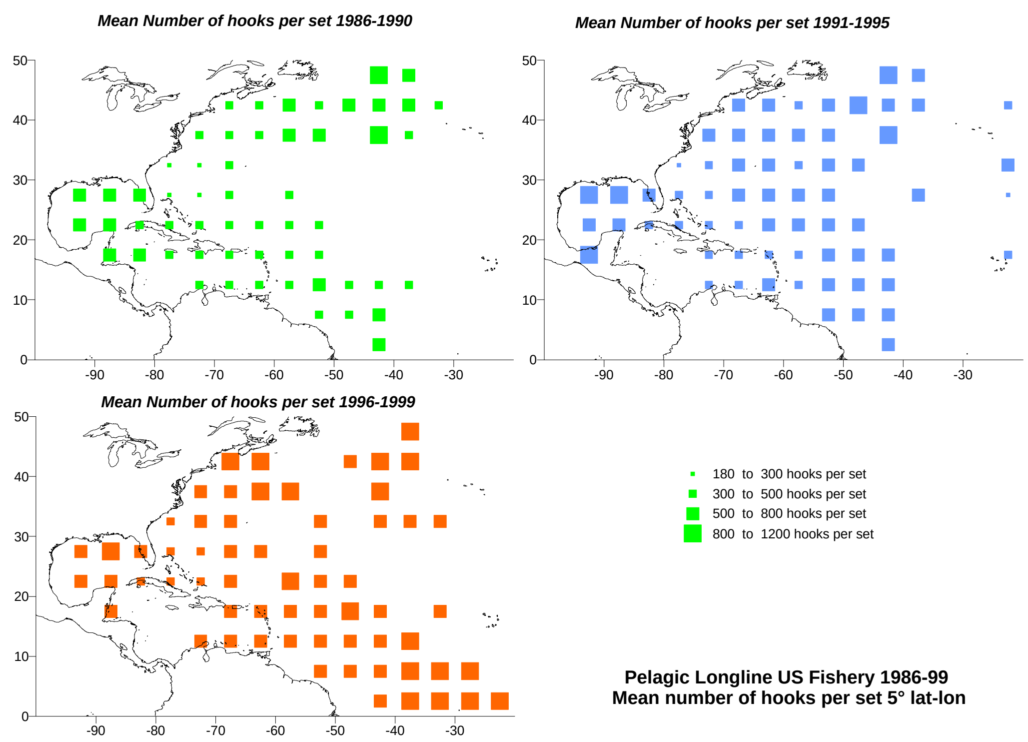


Figure 3. Mean annual fishing effort (number of hooks per set) from the Pelagic Longline US fishery on 5° lat-lon grids.

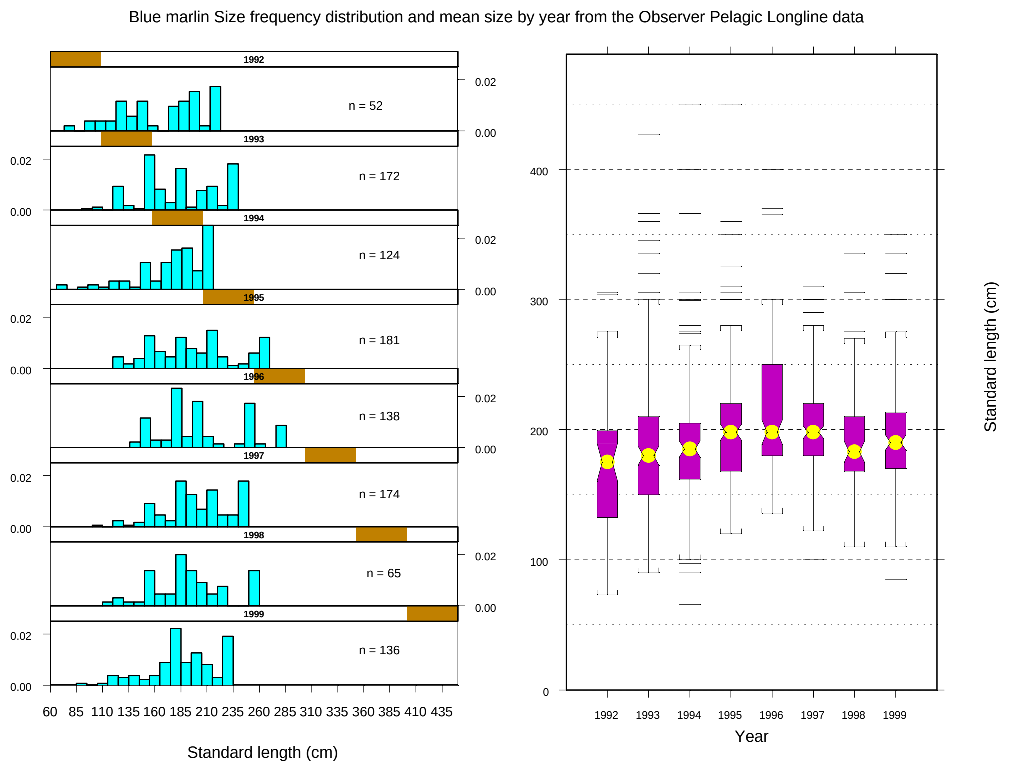


Figure 4. Size frequency distributions by year for blue marlin caught on pelagic longlines by the US fishery fleet. Data summarize from the Observer Pelagic Program of the NMFS.

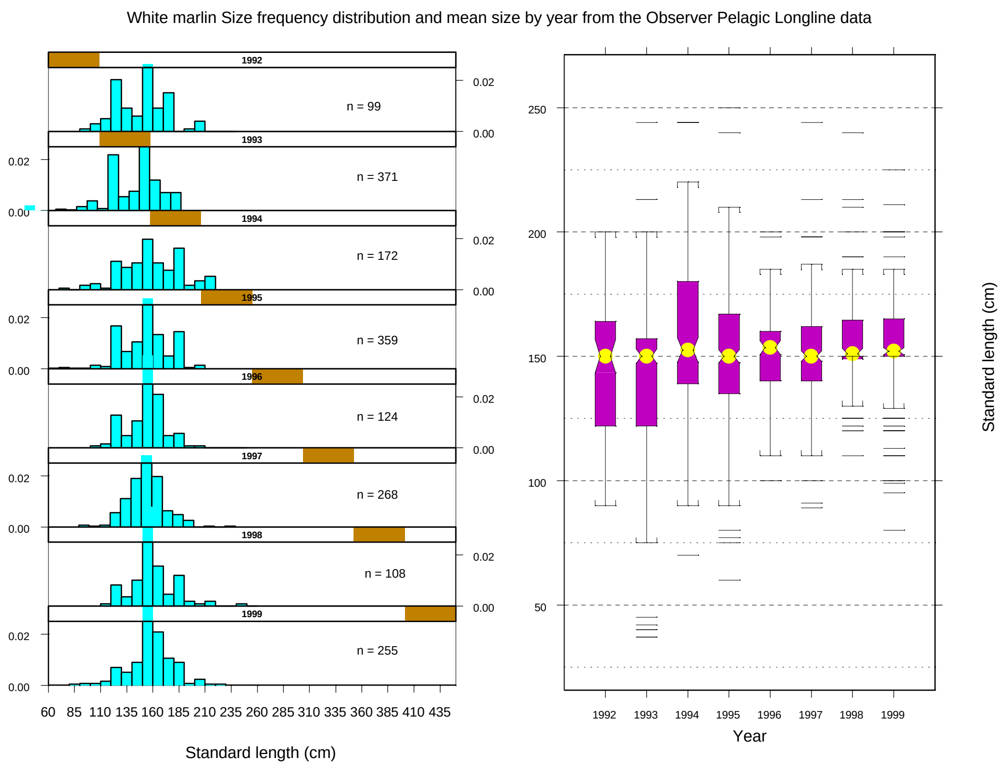


Figure 5. Size frequency distributions by year for white marlin caught on pelagic longlines by the US fishery fleet. Data summarize from the Observer Pelagic Program of the NMFS.

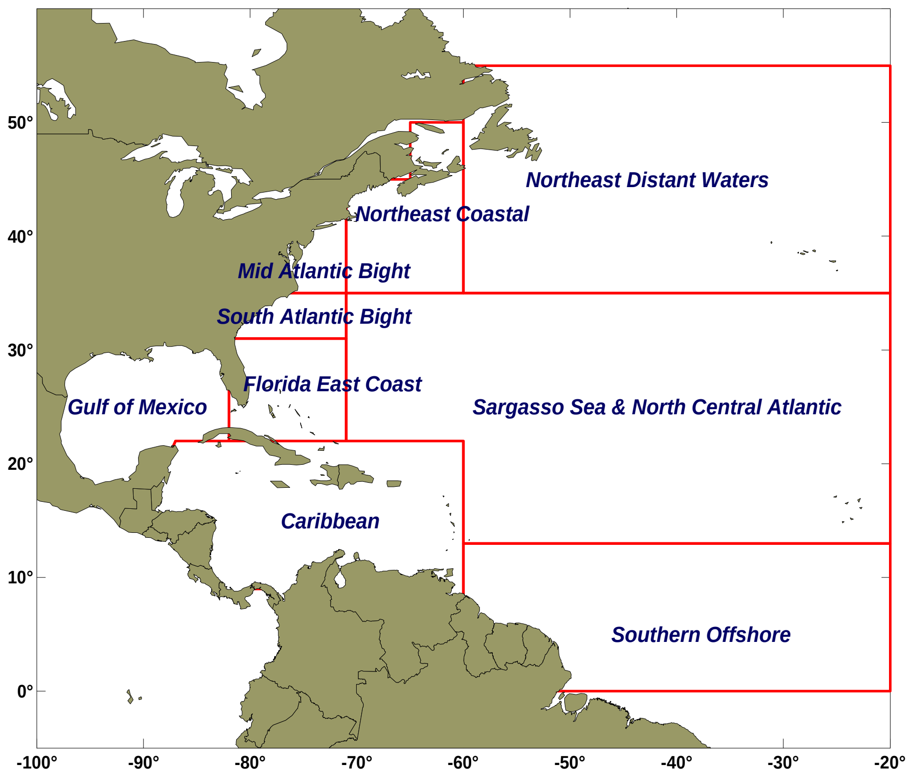


Figure 6. Geographical area classification for the US Pelagic longline fleet

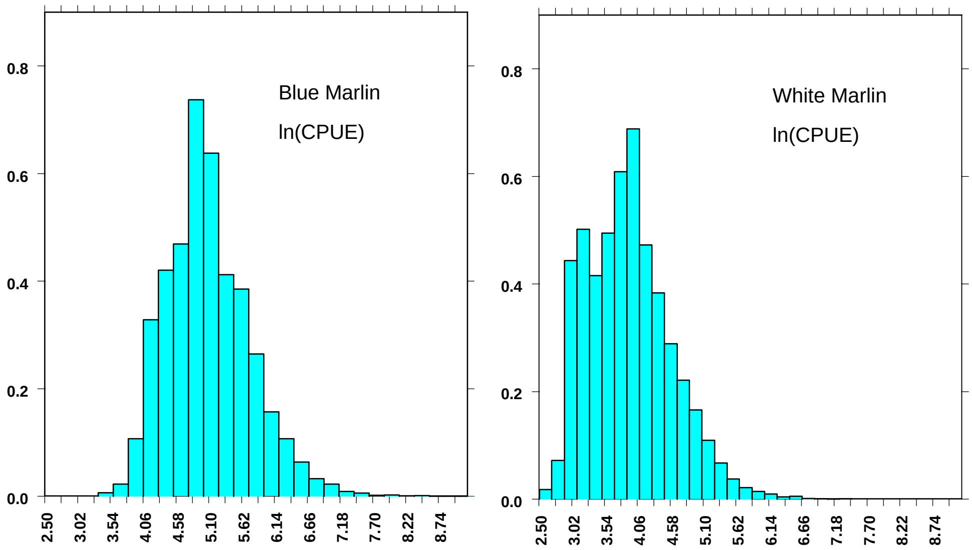


Figure 7. Frequency distribution of log transformed CPUE values for trip/sets that caught blue or white marlin from the Pelagic Longline US fleet from 1986 through 1999.

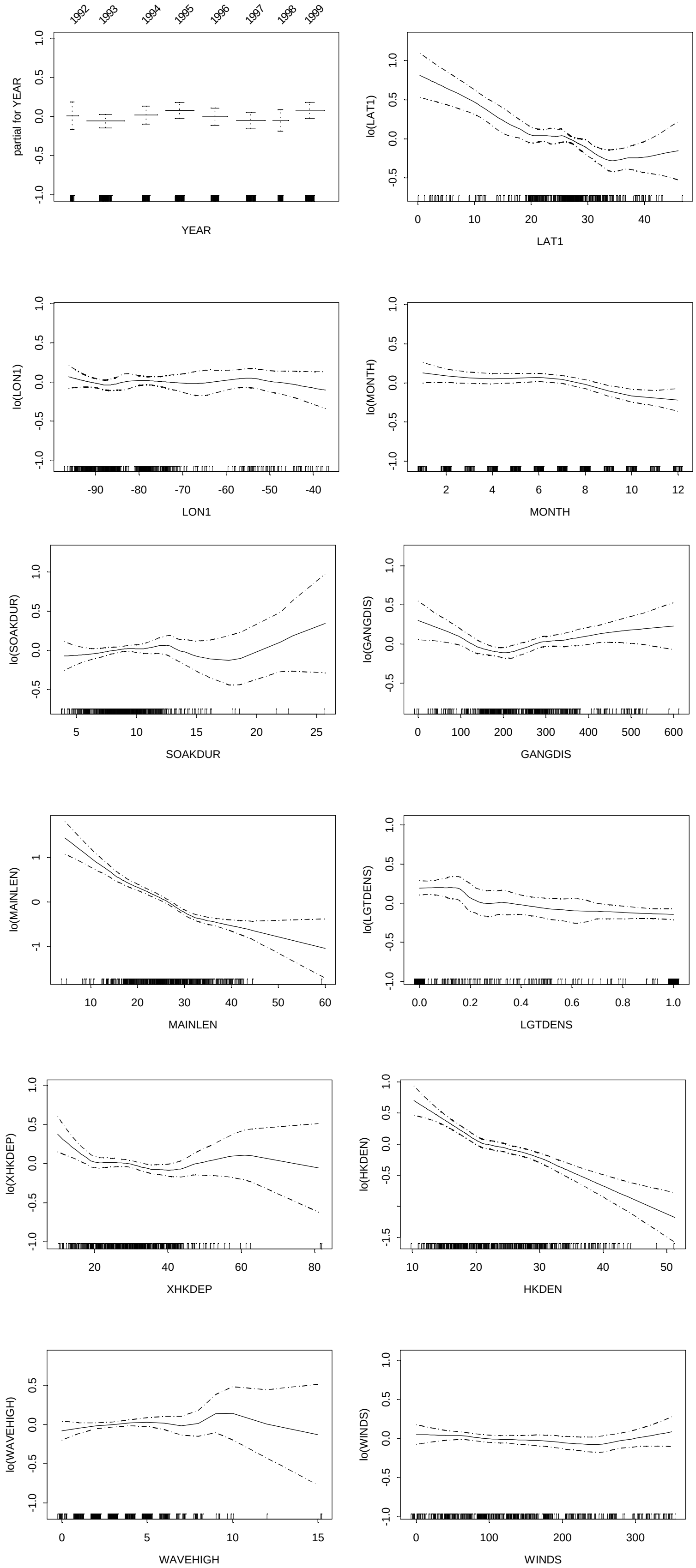
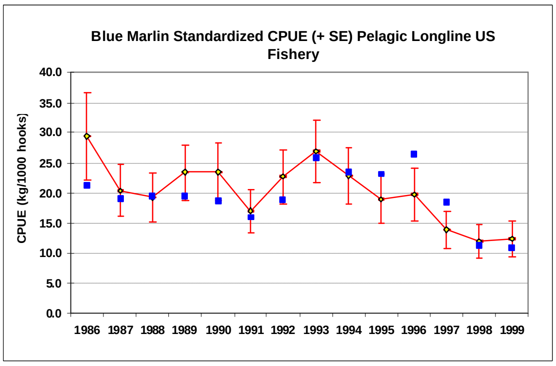


Figure 8. Generalized additive model (GAM) derived effects of latitude (LAT1), longitude (LON1), month, soaking time, distance between gangions (GANGDIS), main line length (MAINLEN), light-stick per hook (LGTDENS), hook depth, hook per unit of main line (HKDEN), wave high and wind source (degrees) on blue marlin nominal CPUE (log transformed) for positive set/trips. Dashed lines indicated the 95% confidence bands, and the x-axis 'rug' plot the relative density of data points.



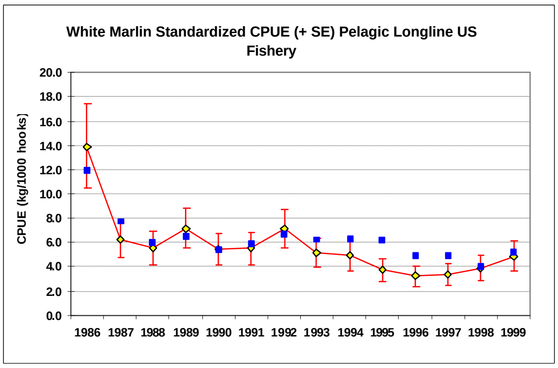
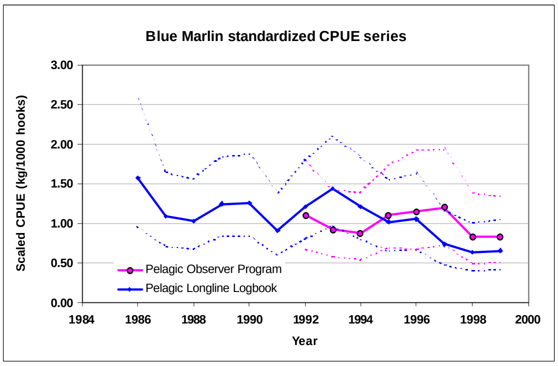


Figure 9. Standardized (squares) and nominal (diamonds) CPUE for blue marlin from the US Pelagic longline fishery. Error bars represents plus minus one standard error.

Figure 10. Standardized (squares) and nominal (diamonds) CPUE for white marlin from the US Pelagic longline fishery. Error bars represents plus minus one standard error.



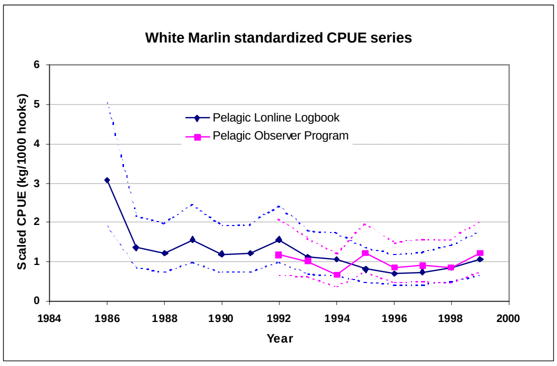
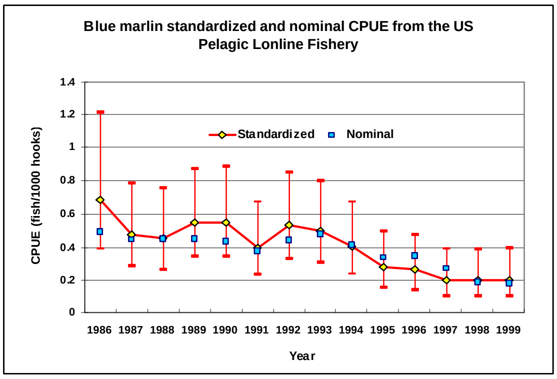


Figure 11. Comparison between the standardized CPUE series from the Pelagic Logbook data and the Observer data for blue marlin catch. Dotted lines represent 95% confidence bounds.

Figure 12. Comparison between the standardized CPUE series from the Pelagic Logbook data and the Observer data for white marlin catch. Dotted lines represent 95% confidence bounds.



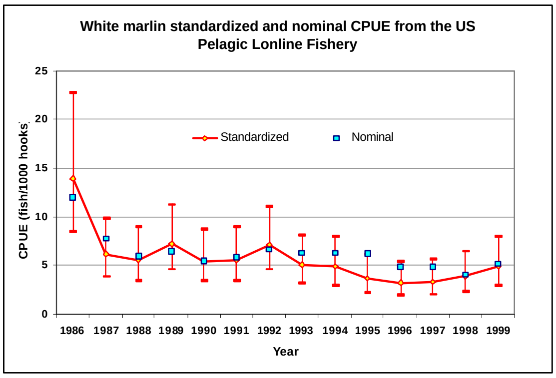
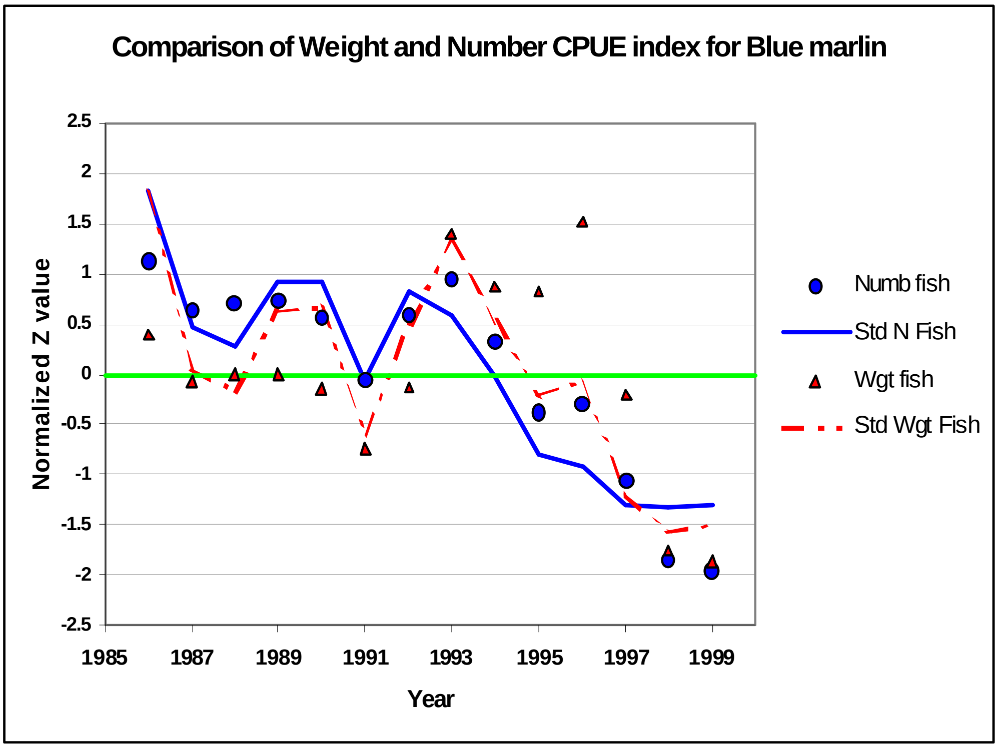


Figure 13. Standardized and nominal CPUE (numbers of fish per 1000 hooks) for blue (left) and white (right) marlin from the US Pelagic longline fishery. Error bars represents 95% confidence intervals.



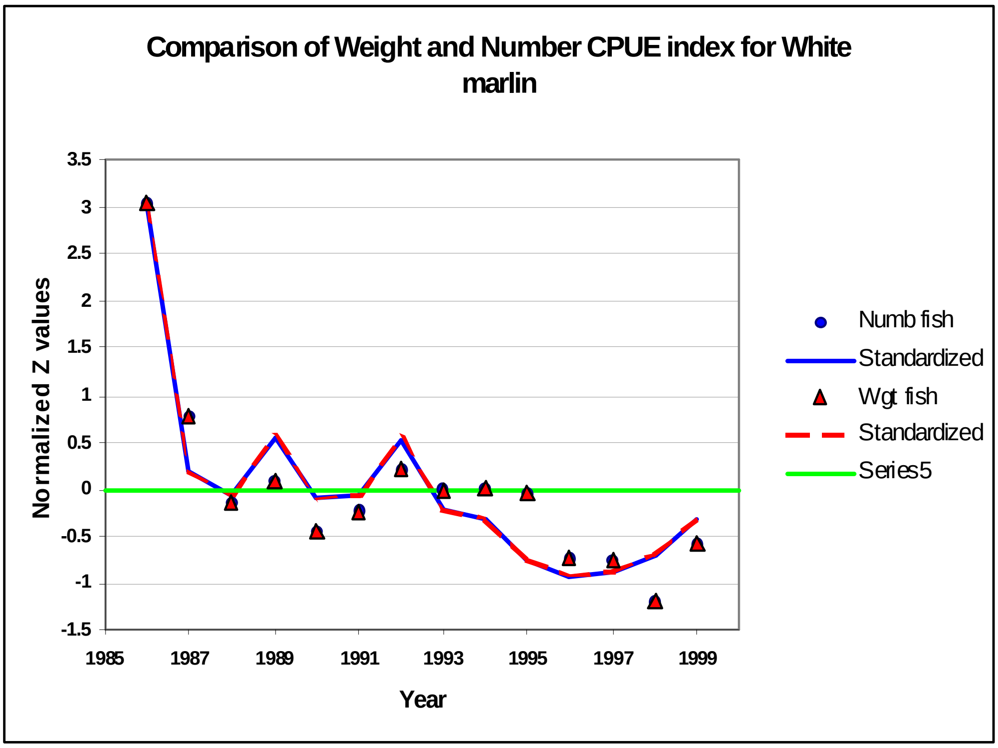


Figure 14. Comparison of standardized CPUE series based on numbers of fish (solid line) or weight of fish (broken line) for blue (top) and white marlin (bottom). Series values were normalized to a mean zero a 1 standard deviation unit. Circles represent the nominal CPUE of numbers of fish per 1000 hooks and triangles represent the nominal CPUE in weight per 1000 hooks.